Substitute Specification

Background of the Invention

The present invention relates to a penetrator for feedthrough of electric power or signals between two locations at different pressures.

Previously known penetrators comprise a plug into which one or more wires are inserted. After the desired number of wires has been inserted, the cavity between the wires is filled with an insulator such as molten glass.
A penetrator of this kind is extremely complicated and expensive to produce. It is best suited for thin signal wires, since the distance between the wires must be in proportion to the strength of the signals. When thicker wires are employed, such as those for electric power, which may have a cross sectional area of 10 mm^2 or larger, it is clear that such penetrators would rapidly become very large and complicated.

It is an object of the invention to provide an improved penetrator which is particularly suitable for use in connection with a power supply. It is a particular object of the invention to provide a penetrator which connects a control unit at low pressure with a motor unit at high pressure and which is intended for use in subsea installations, such as, for example, in connection with the recovery of hydrocarbons.

Summary of the Invention

In a preferred embodiment, the invention concerns a device for the feedthrough of an electrical conductor from one area to another area. The two areas are preferably at different pressures and are separated by a base plate or

a dividing plate through which at least one penetrator is passed. The devices is characterised in that the at least one penetrator comprises a bore for receiving a conductor, for example a copper conductor, a first part with a first shoulder surface, a second part with a second shoulder surface, wherein the shoulder surfaces are designed to abut against each side of the base plate, and at least one spring device which is arranged to keep the shoulder surfaces clamped against the base plate.

The device may also comprise at least one shrink sleeve by which it may be connected to an external cable, and a pair of protective sleeves which are mounted to each end of the device. In a further embodiment of the invention, the device may comprise a nut for pretensioning the spring device. The nut may be screwed onto the end of the conductor.

Further, the invention relates to an underwater electrical actuator comprising a motor unit and a control unit. The motor unit is at ambient pressure and the control unit is at atmospheric pressure. The electrical actuator also comprises a base plate or a dividing plate between the control unit and the motor unit through which one or more penetrators are passed.

The electrical actuator is characterised in that each penetrator comprises a bore for receiving a conductor, for example a copper conductor, a first part with a first shoulder surface, a second part with a second shoulder surface, wherein the shoulder surfaces are designed to abut against each side of the base plate, and at least one spring device which is arranged to keep the shoulder surfaces clamped against the base plate.

The electrical actuator may comprise an additional penetrator for signal cables. The at least one penetrator may transmit high-voltage current between the control unit and the motor unit.

Brief Description of the Drawings

The invention will now be described with reference to the accompanying drawings, in which

Fig. 1 is a partly exploded view of the actuator.

Fig. 2 is a section through the motor illustrating details of the seals.

Fig. 3 is a section through the control unit with the bottom plate.

Fig. 4 is a section through line E-E in fig. 5.

Fig. 5 is a view of the base plate from above.

Fig. 6 is a section through a high-voltage penetrator.

Detailed Description of the Preferred Embodiments

Fig. 1 illustrates an actuator generally indicated by 1 which is designed to actuate a valve between open and closed positions. The actuator is preferably designed to operate a valve that forms part of an installation on the seabed in connection with recovery of hydrocarbons. This comprises a housing 2 which houses an electric motor with a gear. The motor is preferably a brushless direct-current driven motor of a type that is readily available. The gear is preferably a planetary gear with a ratio of 21:1. The planetary gear's ratio may vary and will be selected according to the torque required for the valve spindle. The motor unit forms no part of the invention and will therefore not be described in greater detail.

The housing 2 is sealed against the environment and preferably filled with a hydraulic fluid which is compensated for the ambient pressure. In order to achieve this, a pressure compensator device 15 is mounted on the housing 2 and is fixed by means of bolts to a flange on the housing. The pressure compensator 15 is of a commonly known type where a membrane is influenced on one side by the surrounding sea water and on the other side by the said fluid in the housing 2. The arrangement ensures that the fluid in the housing 2 is at all times under the same pressure as the ambient pressure.

The housing 2 includes a handle 3 which can be operated by a remotely operated underwater vehicle (ROV). A coupling half 6 of an electrical coupling is also mounted on the housing. The coupling half 6 is designed to cooperate with a corresponding coupling half 7 that can be operated by an ROV. Through this coupling, wires are passed for the supply of power as well as communication signals to the motor unit 1. A cable (not shown) which extends from the coupling half 7 is connected to a battery (not shown) for the supply of power and to a unit (not shown) for the communication of signals to the motor unit 1.

On one side of the housing 2 is a flange 9 around which are distributed a number of bolt holes. A base plate or dividing plate 10 is arranged to be placed against the flange 9. The base plate is preferably fixed to the flange by screws (not shown). The base plate supports an electronic control unit 11. The control unit is fixed in turn to the base plate by, for example, screws (not shown). The control unit with its associated parts will be described in greater detail later. A cover housing 13 which encloses and protects the control unit is similarly

equipped with a flange with attachment means, for example bolt holes, thus enabling the housing 13 to be bolted to the flange 9 by bolts 65 and nuts 66.

At the front end of the housing 2 there is provided an anti-rotation sleeve 4 which is designed to engage with back stops (not shown) on the subsea installation. The anti-rotation sleeve 4 has a flange 5 for attachment to a corresponding flange 5a on the housing 2 by means of bolts 12. The motor unit has a drive shaft 14 designed to engage with and transmit rotation to a valve spindle for a valve on the subsea installation. The said parts, which are designed for engagement with the valve, are of a type that is well known to a person skilled in the art and are therefore not described further.

If the valve is of the sliding type, such as a slide valve, a converter may be provided in connection with the drive shaft or the valve spindle for changing rotation to linear motion.

The actuator 1 also comprises a locking device for locking the actuator to the subsea installation. It consists of a spring-loaded locking dog 17 which is connected via a flexible rotating joint 18 with a handle 19 that can be operated by means of an ROV tool. The locking dog 17 is moved by means of the handle 19 between a locked and an open position. The locking device also comprises a spring-loaded arm 16 for absorbing any misalignments on the valve spindle.

The drive shaft 14 is hollow, thus enabling the end of a valve spindle to be inserted therein. With reference to fig. 2, the drive shaft consists of a rear end 21 which is attached to the gear's output shaft, an internal intermediate portion 22 whose internal cross section is asymmetrical, preferably hexagonal, an external

intermediate portion 23 with a cylindrical internal cross section and a front portion 24 which is extended outwards in order to form an inlet funnel for the valve spindle. The first intermediate portion has a portion with a larger diameter, thus forming a projecting flange 25. The flange's internal edge is arranged to abut against and be supported by the gearbox. A distance ring 26 of approximately the same thickness as the flange has an inner surface that is intended to abut against and be supported by the gearbox. A clamping ring 27 is provided outside the distance ring 26. The distance ring and the clamping ring have holes for passing through bolts 28 which can be screwed into bolt holes 29 in the gearbox. As shown in the figure, when the parts are assembled and the bolts 28 screwed into the gearbox, the drive shaft will be secured in operative connection with the gearbox. The clamping ring 27 and the distance ring 26 rotate together with the drive shaft.

As also illustrated in fig. 2, a non-rotating part 8 of the gear unit has a circumferential flange that is arranged to be clamped between the flanges 5 and 5a by means of the bolts 12. This secures the gearbox in the housing 2.

To provide protection against any overloading of the motor against the valve spindle, shear pins (not shown) may be provided between the flange 25 and the distance ring 26.

To prevent sea water from penetrating into the motor, the motor unit is sealed against the sleeve 4 and the housing 2 by a number of seals. These comprise a first O-ring 28 mounted between the gearbox and a flange on the distance ring. A second O-ring 29 is mounted between the sleeve 4 and the

gearbox portion 8. A third O-ring 30 is mounted between the housing 2 and the gearbox portion 8. The O-ring 28 is thereby located between the two parts 26 and 21 with the same rotation and the O-rings 29 and 30 are located between the non-rotating parts 2, 4 and 8. In order to provide a seal between the non-rotating sleeve 4, the non-rotating part 8 of the gearbox and the rotating ring 26, a dynamic seal 31 is mounted located between the outside of the ring 26 and the sleeve 4. It is engaged with a corresponding seal (not shown) mounted on the gearbox. The seal 31 is advantageously a lip seal. An injection nipple 32 for grease is also provided in the protective cover. Grease can thereby be injected between the seals 29 and 31, acting as a safeguard against penetration of sea water into the motor. If so desired the grease can be injected under a pressure that is slightly higher than the ambient pressure.

In the control unit 11, electronics are provided for controlling the motor, for receiving and transmitting signals to a remotely located control station, and for sensing the condition of the motor and the position of the valve. The housing 13 for the control unit 11 is filled with nitrogen under atmospheric pressure, i.e. 1 bar. The nitrogen gas is inert and helps to protect the electronic components inside the housing, according to normal practice. To ensure a seal in the connection between the flange 9 and the housing 13, O-rings 70, 71 are provided.

Through the base plate 10 extend a number of holes which are arranged to receive and pass through corresponding penetrators 101-105 for the feedthrough of cables supplying power to the motor. An additional hole receives

a second penetrator 106 for feedthrough of signals between the motor unit and the control unit. The penetrator 106 is of a common multipin type where the wires are embedded in glass for protection. The base plate 10 further comprises a filler port 107 and a test port 108. The test port 108 is connected with a channel 63 and is employed for injecting an inert gas, preferably helium, under pressure in order to test the seals 72, 73. The test port also tests the seals around the penetrator, which will be described in greater detail later. The filler port 107 is used for filling the housing 13 with nitrogen when preparing the unit for lowering to the subsea installation. A breaking pin 109 is also provided which is arranged to be broken if the pressure in the housing 13 exceeds the pressure in the actuator housing 2. It works by opening a port between the two units in order to bleed off the pressure in the housing 13. This may happen particularly if fluid from the motor housing leaks into the housing 13 during the actuator's stay on the seabed. During recovery of the equipment, the pressure in the housing 13 may become so great that there is a risk of the cover being blown off when the screws 65 are loosened. When the breaking pin is activated the housing 13 can be emptied of overpressure fluid.

The penetrators 101-105 are designed to transfer high-voltage current between the control unit 11 and the motor. As illustrated in fig. 5, five such penetrators, which are marked 101-105, are provided, three of which are designed to supply three-phase current (1 per phase) from the current supply and two of which are designed to supply direct current to the motor.

We shall now refer to fig. 6, which illustrates the penetrator in greater detail. Each penetrator comprises an insulator sleeve 111 which includes a through-going bore 120 that is designed to receive and pass through an electric conductor, e.g. a copper conductor, a first portion 112 and a second portion 113 that has a larger diameter than the first portion. The second portion 113 has a lower end surface 124 and an upper end surface that forms a shoulder surface 114. An attachment sleeve 116 has an internal bore 151 whose diameter is equal to the diameter of the first portion 112 of the insulator sleeve 111, thus enabling the sleeve to be fitted with little clearance onto the first portion 112 of the insulator sleeve 111. The attachment sleeve 116 has a lower end surface that forms a shoulder surface 117 and an upper end surface which is undercut to form a recess 152. The outer diameter of the sleeve 116 is equal to the diameter of the second portion 113 of the insulator sleeve 111, with the result that when the parts are assembled, a bushing sleeve in the form of a reel is obtained. In the transition between the shoulder surfaces 114 and 117 respectively, O-rings 118 and 119 respectively are mounted for sealing between the insulator sleeve and the base plate 10. The insulator sleeve 111 is preferably made of an insulating material, such as a PEEK-type material.

The conductor comprises a first portion 121 with an outer diameter equal to the diameter of the bore 120 in the insulator sleeve 111, thus enabling the conductor to be passed through the bore 120 with relatively little clearance. The conductor is provided with threads 128 at its upper end. A portion 122 of the conductor has a larger diameter in order to form a flange 122, bounded by upper

125 and lower 153 shoulder surfaces. A receiving portion 123 is designed to be connected to a cable 129. The flange 125 is designed to abut against the end 124 of the insulator sleeve 111.

A rubber or other type of protective sleeve 126 is fitted over the end portion 113, the flange 122 and the receiving portion 123 in order to enclose and protect these parts. In addition, an O-ring 127 is mounted between the flange 125 and the end surface 124.

The recess 152 of the sleeve 116 is designed to receive a spring device. The spring device comprises an O-ring 147, a spring washer 141, a spring 142 and a retainer washer 143. The retainer washer 143 abuts against the upper end surface of the attachment sleeve 116. A nut 144 can be screwed onto the threads 128 after mounting the spring device in order to join the parts together, while at the same time the spring is compressed until the retainer washer 143 abuts against the upper end of the attachment sleeve 116.

The penetrator is assembled as follows. First, the O-ring 119 is inserted onto the portion 112 of the insulator sleeve until it abuts against the shoulder 114. The insulator sleeve is then passed through the bore in the base plate 10. The O-ring 127 is fitted onto the copper conductor and the copper conductor is passed through the bore 120 until the flange 125 abuts against the end 124 of the insulator sleeve. The O-ring 118 is pushed onto the end of the portion 112 until it abuts against the base plate 10. The attachment sleeve 116 is now pushed over the conductor until it abuts against the base plate 10. The O-ring 147, the spring washer 141, the spring 142 and the retainer washer 143 are

mounted and the nut 144 is screwed onto the conductor until the retainer washer abuts against the upper edge of the attachment sleeve 116. A shrink sleeve 145 that extends to the control unit can now be screwed onto the end of the conductor 121. A conductor for a cable can now be soldered or shrunk onto the shrink sleeve 145.

Finally, the protective sleeves 126, 146 are shrunk onto the outside of the upper and lower parts of the penetrator.

As illustrated in the figure the length of the portion 112 between the end surfaces 114 and 117 corresponds to the thickness of the base plate 10 (figs. 3 and 4). With the spring 142 pretensioned, a force will be obtained which causes the base plate 10 to be gripped between the attachment sleeve 116 and the insulator sleeve's flange shoulder 114 with a force that compresses the O-rings 118 and 119, thus providing a good seal. In addition, the spring device will permit the penetrator to be easily adapted to different thicknesses of the plate 10 and/or compensate for unevenness in the plate thickness.

This is repeated for all the penetrators, and the cables that are attached to the end of their respective conductors can now be attached to contacts in the control unit 11. At the same time, the penetrator 106 is passed through the base plate 10 and connected to the motor and the control unit, respectively. The cover housing 13 is then attached to the flange 9.

After the flange 9 is mounted on the housing 13, the bushings, i.e. the seals 72, 73 together with the seals 118, 119 can now be tested. A gas, preferably helium, is forced through the test port 108 in order to test whether the

connection between the penetrators and the plates is completely gas-tight. Finally, the interior of the control unit is filled with nitrogen gas.

During operation, the actuator is brought down to the seabed by means of an ROV. The handle 3 is used to hold the actuator and to steer it into engagement with the receiver, i.e. a valve spindle.

When mounting the actuator on the installation, the actuator is moved over to the valve. The funnel-shaped opening of the drive shaft is arranged to be fitted over the valve spindle, thus enabling the valve spindle to be moved into engagement with the hexagonal cross section in the portion 22 of the drive shaft 14. At the same time, the grooves of the anti-rotation sleeve 4 will engage with corresponding pins on the subsea installation or the valve housing, thus forming a back stop that prevents the actuator housing from being turned when the motor is rotated. The handle 19 is then rotated by means of an ROV tool in order to rotate the locking mechanism 17 via the rotating joint 18. This will move the locking mechanism to a locked position against a corresponding locking part provided on the valve housing, or against the valve spindle. Further rotation will cause the spring 16 to be stretched/tensioned, providing a "floating" contact of the actuator.